ELECTROWEAK RESULTS FROM CDF

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Inclusive W and Z production cross-sections have been measured by CDF and certain electroweak parameters extracted with high precision from these measurements. New results on diboson production at the Tevatron are also presented.

1. Introduction

Inclusive W and Z production cross-section measurements have played a key role in understanding the Run 2 CDF detector and are of sufficient accuracy to allow the extraction of certain electroweak parameters with a similar precision to the current world data. Diboson production cross-sections are much smaller but offer an important testing ground for the electroweak Standard Model.

2. W and Z Cross-Section Measurements

The W and Z cross-sections have been measured in both electron and muon channels using 72 pb^{-1} of Run 2 data. Electrons with $E_T > 25$ GeV in the rapidity region $|\eta^e| < 1.0$ (extending to $|\eta^e| < 2.8$ for the second leg in $Z \to e^+e^-$ events) and muons with $p_T > 20$ GeV/c and $|\eta^\mu| < 1.0$ are selected. The missing-E_T is required to be greater than 25 GeV (20 GeV) in the $W \to e\nu$ ($W \to \mu\nu$) channels. The most important backgrounds (ranging from $\approx 9\%$ in the $W \to \mu\nu$ channel to $< 1\%$ in the $Z \to \mu^+\mu^-$ channel) are QCD events with fake leptons and missing-E_T and backgrounds from other electroweak processes (for example W and Z decays involving taus or Z events with "lost-legs"). The measured cross-sections are consistent in electron and muon channels and have been combined to give :

*on behalf of the CDF collaboration

$$\sigma(p\bar{p} \to W \to l\nu) = 2777 \pm 10(\text{stat}) \pm 52(\text{syst}) \pm 167(\text{lumi})\ \text{pb},$$
$$\sigma(p\bar{p} \to Z/\gamma^* \to l^+l^-) = 254.3 \pm 3.3(\text{stat}) \pm 4.3(\text{syst}) \pm 15.3(\text{lumi})\ \text{pb}.$$

Large systematic error sources are uncertainties related to PDF's, lepton identification, QCD background subtraction and knowledge of the material distribution in the CDF detector. The measurements are compared to NNLO theory [1] as well as previous measurements in figure 1. The agreement is excellent. Interestingly, both the experimental systematic error and the theory uncertainty on the W production cross-section are now less than the 6% uncertainty on the CDF luminosity determined using the total inelastic cross-section, indicating the usefulness of W production at the Tevatron (and more so, at the LHC) for measuring integrated luminosities.

2.1. $W \to \tau\nu$

CDF can trigger on hadronic tau decays in association with large missing-E_T in Run 2. Tau reconstruction algorithms use a combination of tracks and π^0's reconstructed in the calorimeter to form candidates. Backgrounds are kept under control at the $\approx$ 25% level, and the charge multiplicity distribution is well described by the combination of signal and expected backgrounds. The final result on 72 pb^{-1} of data :

$$\sigma(p\bar{p} \to W \to \tau\nu) = 2.62 \pm 0.07(\text{stat}) \pm 0.21(\text{syst}) \pm 0.16(\text{lumi})\ \text{nb},$$

is in excellent agreement with the measurement in the electron and muon channels. This analysis has established and validated many of the hadronic

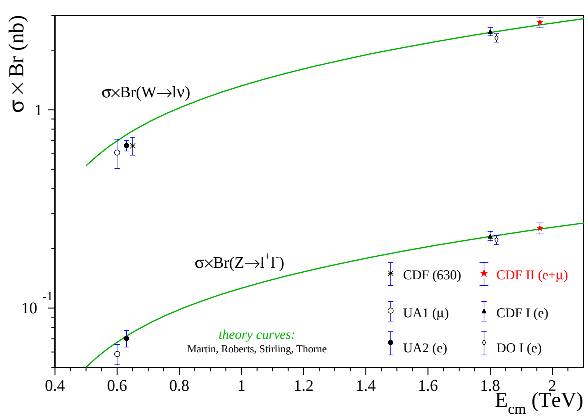

Figure 1. Run 2 measurements of the leptonic W and Z cross-sections compared to next-to-next-to leading order theory and previous measurements.

tau identification techniques that will be applied to searches for physics beyond the Standard Model at CDF.

2.2. *Indirect determination of the W width*

Many experimental systematics cancel in the ratio of W and Z leptonic decay cross-sections, which can be re-written in the following form :

$$R = \frac{\sigma(W)\times \mathrm{BR}(W\to l\nu)}{\sigma(Z)\times \mathrm{BR}(Z\to l^+l^-)} = \frac{\sigma(W)}{\sigma(Z)} \times \frac{\Gamma_{W\to l\nu}}{\Gamma_W} \times \frac{\Gamma_Z}{\Gamma_{Z\to l^+l^-}}.$$

The ratio of inclusive cross-sections at 1.96 TeV is calculated to be 3.3677 ± 0.0058 [3]. The leptonic partial width of the W boson is also calculated in the Standard Model to be 226.4 ± 0.3 MeV and the leptonic branching ratio of the Z is measured to better than one part per thousand at LEP. The measured value $R = 10.93 \pm 0.15(\mathrm{stat}) \pm 0.14(\mathrm{syst})$ then yields an indirect determination of the W width :

$$\Gamma_W^{\mathrm{tot}} = 2072 \pm 40 \text{ MeV}$$

This compares well with the current world average (combining direct and indirect measurements but not using the LEP 2 results on $\mathrm{BR}(W \to l\nu)$) of 2118 ± 42 MeV [2]. Other important tests of the Standard Model flow from precise W and Z cross section determinations [3].

3. Diboson Cross-Section Measurements

3.1. $W/Z + \gamma$

Events containing leptonic (e,μ) decays of W and Z bosons are selected in a very similar manner to that described in section 2. Radiative events must in addition contain central photons ($|\eta^\gamma| < 1.1$) with $E_T^\gamma > 7$ GeV. Requiring that the photons are well separated from the final state leptons ($R_{\eta\phi}(l,\gamma) > 0.7$) reduces the less interesting contribution from small angle final state radiation. Detailed studies of the rate at which jets can fake photons yield background estimates from $W + \mathrm{jet}$ ($Z + \mathrm{jet}$) production at the level of $\approx 20\%$ ($\approx 6\%$) of the total event yields in the $W\gamma$ ($Z\gamma$) channels. Other electroweak backgrounds are much smaller and are more straightforward to compute. Kinematic distributions such as those displayed in figure 2 show good agreement between the data and the combined expectation from signal and background. Measured cross-sections corresponding to the above kinematic regions are :

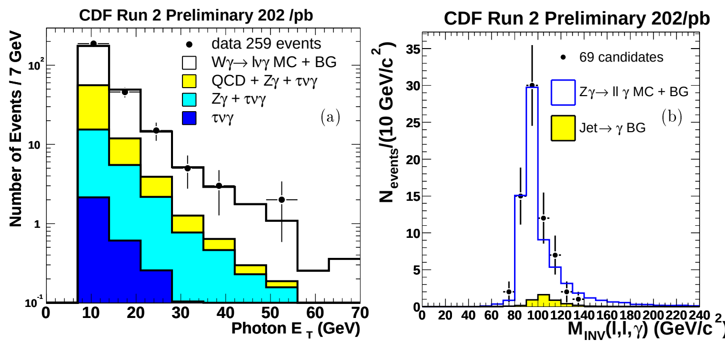

Figure 2. The photon E_T distribution for $W(\gamma) \to l\nu\gamma$ events (a) and the 3-body invariant mass distribution for $Z(\gamma) \to l^+l^-\gamma$ events (b).

$$\sigma_{W(\gamma)\to l\nu\gamma} = 19.7 \pm 1.7(\text{stat}) \pm 2.0(\text{syst}) \pm 1.1(\text{lumi})\ \text{pb},$$
$$\sigma_{Z(\gamma)\to l^+l^-\gamma} = 5.3 \pm 0.6(\text{stat}) \pm 0.3(\text{syst}) \pm 0.3(\text{lumi})\ \text{pb},$$

which compare well with the NLO predictions of 19.3 ± 1.4 and 5.4 ± 0.3 pb respectively [4]. The optimising of cuts for $WW\gamma$ anomalous coupling sensitivity is underway. Clear evidence of the expected radiation amplitude zero in $W + \gamma$ production is expected with increased luminosity.

3.2. *WW*

Two analyses have searched for WW production in the dilepton decay channel $WW \to l^+l^-\nu\bar{\nu}$ $(l = e, \mu)$ in Run 2. A high-purity analysis ("DIL") makes the same quality requirements on both leptons as those in the analyses described above, which gives good control particularly over backgrounds involving fake leptons. A high-acceptance analysis ("LTRK") loosens the requirements on the second lepton, demanding only a well-measured and well-isolated track. The analyses also employ somewhat different topological cuts, such as those designed to reject Drell-Yan events with large fake missing-E_T [5]. Overall, the two analyses estimate :

$$\begin{array}{ll}
\textbf{DIL}: & N_{WW}^{\text{predict.}} = 11.3 \pm 1.3 \quad N_{\text{back.}}^{\text{predict.}} = 4.77 \pm 0.70 \quad N_{\text{DATA}} = 17 \\
& \sigma(WW) = 14.3^{+5.6}_{-4.9}(\text{stat}) \pm 1.6(\text{syst}) \pm 0.9(\text{lumi})\ \text{pb} \\
\textbf{LTRK}: & N_{WW}^{\text{predict.}} = 16.3 \pm 0.4 \quad N_{\text{back.}}^{\text{predict.}} = 15.1 \pm 0.9 \quad N_{\text{DATA}} = 39 \\
& \sigma(WW) = 19.4 \pm 5.1(\text{stat}) \pm 3.5(\text{syst}) \pm 1.2(\text{lumi})\ \text{pb}
\end{array}$$

Both cross-section determinations are in agreement with the NLO prediction $\sigma(WW) = 12.5 \pm 0.8$ pb [6] and are in statistical agreement with one

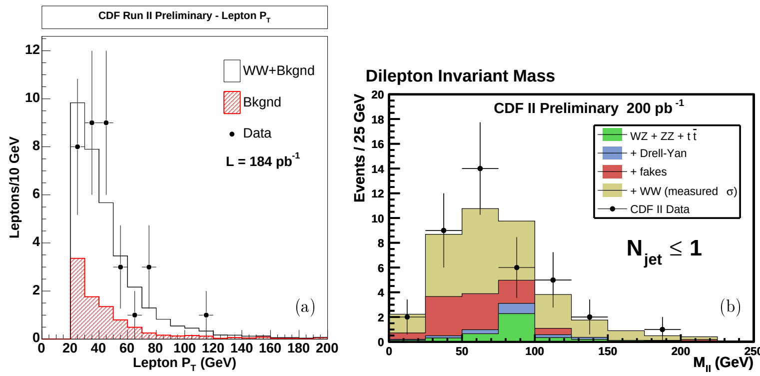

Figure 3. The lepton transverse momentum distribution for the DIL WW analysis (a) and the dilepton invariant mass distribution for the LTRK WW analysis (b).

another given a relatively small overlap in acceptance. Kinematic distributions, examples of which are shown in figure 3, show good agreement between data and expectation.

4. Conclusions

Precision measurements of the inclusive W and Z production cross-sections have been made by CDF in Run 2. Radiative W and Z production have been studied and appear to be well described by the Standard Model. A signal for W-pair production in hadronic collisions has been established with high significance for the first time. These and other measurements will improve rapidly as larger luminosities are collected.

Acknowledgments

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References

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